and the American Republic in particular, whether in our own eyes or in the eyes of other nations and later times, they will come to the conclusion that more glory, honor and love are to be won by national justice, sincerity, patience in failure and generosity in success than by national impatience, combativeness and successful self-seeking—and glory, honor and love more by as much as the virtues and ideals of civilized man excel those of barbarous men.

A HALF-CENTURY OF EVOLUTION, WITH SPECIAL REFERENCE TO THE EFFECTS OF GEOLOGICAL CHANGES ON ANIMAL LIFE (II.).*

THE APPALACHIAN REVOLUTION AND ITS BIOLOGICAL RESULTS.

UNLESS we except the great changes in physical geography which took place at the end of the Tertiary period, when the mountain chains of each continent assumed the proportions we now see, the Appalachian revolution, or the mountain-building and continent-making at the close of the Paleozoic age, was the most extensive and biologically notable event in geological history. In its effect on life, whether indirect or direct, it was of vastly greater significance than any period since, for contemporaneous with and as a consequence of this revolution was the incoming of the new types of higher or terrestrial vertebrates. Through the researches, now so familiar, in the field and study of the two Rogerses, of Dana and of Hall, we know that all through the Paleozoic era at least some 30,000 to 40,000 feet of shoal water sediments, both marine and fresh-water, derived from the erosion of neighboring lands, were accumulated in a geosynclinal trough over the present site of the range extending from near the mouth of the St. Lawrence to northern Georgia. At the end of the era ensued a series of movements of the earth's crust resulting from the weight of this vast accumulation, which in a geologically brief period sank in, dislocated and crushed the sides of the trough, and folded the strata into great close parallel folds, besides inducing more or less metamorphism. These folds rising from a plateau formed mountain ranges perhaps as high as the Sierra Nevada or Andean Cordillera of the present day. The plateau emerged above the surface of the Paleozoic ocean, and was carved and eroded into mountain peaks, separated by valleys of erosion, the rivers of the Appalachian drainage-system cutting their channels across the mountain ranges.

But this process of mountain-building and erosion was not confined to the end of the Paleozoic era. Willis * has shown that there were several successive cycles of denudation, covering a period extending from the end of the Paleozoic era to the present time. And it is the fact of these successive cycles of denudation both on the Atlantic and Pacific slopes of our continent that is of high significance to the zoologist from the obvious bearings of these revolutions on the production of variations. Indeed, it is these phenomena which have suggested the subject of this address.

We can imagine that this great plateau, in the beginning of the Mesozoic era, with its lofty mountain ranges and peaks rising from the shores of the Atlantic, presented different climatic zones, from tropical lowlands, with their vast swamps, to temperate uplands, stretching up perhaps to alpine summits, with possibly glaciers of limited extent filling the upper parts of the mountain valleys. New Zealand at the present day has a subtropical belt of tree ferns, while the mountains bear glaciers on their summits ; and in Mexico, only about

* Address of the Vice-President before Section F—Zoology—of the American Association for the Advancement of Science, August, 1898 ; continued from SCIENCE, August 27th.

* National Geographic Magazine, 1889, Vol. I., pp. 291–300.

20° from the tropics, rising above the tropical belt, is the temperate plateau, and farther up the subalpine snow-clad summits of Popocatapetl, Orizaba and other lofty peaks. So in the Appalachians of the Paleozoic the cryptogamous forests and their animal life may have been confined to the coastal plains and lowlands, while on the higher, cooler levels may have existed a different assemblage of life; and it is not beyond the reach of possibility that a scanty subalpine flora peopled the cooler summits.

But the unceasing process of atmospheric erosion and river action continued through the Jurassic, which was, as stated by Scott, in his Introduction to Geology, 'a time of great denudation, when the high ranges of the Appalachian mountains were much wasted away, and the newly upheaved, tilted and faulted beds of the Trias were deeply eroded.' At about the time of the opening of the Cretaceous the range was reduced to a peneplain (the Cretaceous peneplain), with only vestiges of once lofty mountains; the scenic features roughly recalling those of North Carolina and New England at present, although more subdued and featureless, more like the Kittatinny peneplain of the Piedmont district at the eastern base of the Blue Ridge to-day as contrasted with the present mountain region of Pennsylvania and New Jersey. There were also extensive changes in the interior. What was the Colorado island was added to the mainland, and a great Mediterranean sea extended from the Uinta mountains of southeastern Wyoming to New Mexico and Arizona, and stretched from the Colorado peninsula westward to Utah. In the upper Jurassic as the result of a depression a gulf was formed over northern Utah, Wyoming and southern Montana (Scott).

The formation of this Cretaceous peneplain was succeeded by a re-elevation, and the surface which is now Virginia was gradually raised to a height of 1,400 feet, and again the sluggish rivers of the Cretaceous times were revivified, cutting through the harder strata forming the walls of the longitudinal valleys and, widening into broad estuaries, emptied into the Atlantic.

In the Eocene Tertiary, as Willis tells us: "The swelling of the Appalachian dome began again. It rose 200 feet in New Jersey, 600 feet in Pennsylvania, 1,700 feet in southern Virginia and thence southward sloped to the Gulf of Mexico." In consequence of the renewed elevation the streams were revived; and Willis adds: "Once more falling swiftly they have sawed, and are sawing, their channels down, and are preparing for the development of a future base-level."*

We can in imagination see, as the result of these widespread physical changes, inducing as they must have done the formation of separate basins or areas enclosed by mountain ranges, with different climates and zones on land, however uniform might have been the general temperature of the world at that time and the other physical conditions of the sea—we can imagine the profound and deep-seated influence thus exerted on the life-forms peopling the uneven surface of the land.

The vegetation of the lowlands was rich and luxuriant, as the Triassic (Newark), coal deposits near Richmond testify, and, while the uplands and hills were probably clad with dense forests of conifers, on the dryer desert areas of the peneplain the trees may have been more scanty, like the scattered pines of the dryer elevated region of the Southwest and of the Great Basin at the present day. The distribution of the animal life must have corresponded; one assemblage, especially the amphibians, characterizing the hot and humid lowlands;

*Quoted from Scott's Introduction to Geology, p. 342.

another the cooler uplands, while already erhaps a few for ms became adapted to the more arid desert areas, as is the case now in Australia, which is in a sense a Mesozoic continent.

Similar subsidences and elevations changed the Jurassic map in Eurasia. This continent was already a land mass of great extent, and fresh-water lakes extended across Siberia, and in China were extensive swamps and submerged lands, now represented by coal fields. Afterwards in the middle Jura this continent subsided, and the Jurassic sea covered the greater part of Europe and Asia, this being, according to Neumayr, 'one of the greatest transgressions of the sea in all recorded geological history.' Subsidences and elevations resulted, it is supposed, in cutting off India from Eurasia, so that the strait or sea covered the site of the Himalayas, and India was possibly joined to Australia, the Malaysian peninsula forming the connecting link; or perhaps it stretched to the southwestward and was joined to South Africa. However this may be, it is sufficient for our present purpose that these vast changes in the relative position of land and sea were productive of a corresponding amount of variation and perhaps of immigration and consequent isolation. At all events, throughout the Jurassic seas as a whole there seemed to have been remarkable faunal differences. This led Neumayr, in which he is followed by Kayser,* to conceive that there were already in Jurassic times climatic zones corresponding to the boreal, polar, north and south temperate and tropical zones of the present day. If, however, with Scott, we reject this view and substitute for it the supposition that 'the marked faunal differences are due to varying facies, depth of water, character of bottom, etc., and even more to the partly isolated sea-basins and the changing connections which were established between them,' it is of nearly the same import to the geological biologist, for these varying conditions of the Jurassic ocean bottom could not have been without their influence in causing variation, modification and adaptation to this or that set of conditions of existence.

*Text-book of Comparative Geology, translated and edited by Philip Lake, p. 270, 271.

Turning now to the effects of the Appalachian revolution on the life of that time we see that the biological results were, in the main, in conformity with the geological changes. During the Carboniferous period vertebrates with limbs and lungs appeared, *i. e.*, the labyrinthodonts or Stegocephala. They were, compared with the other orders of their class, the most composite and highly organized of the Amphibia.

Throughout the long period of comparative geological quiet, those long ages of preparation which ended in the crisis or cataclysm which closed the Paleozoic, the amphibian type was slowly being evolved in the swamps and bayous of the lowlands of the Devonian, whose vegetation so nearly anticipated that of the Carboniferous from some Devonian* or late Silurian ganoids, from which diverged on the one hand Dipterus and the colossal lung-fish (Dinichthys and Titanichthys, of the Devonian, and perhaps on the other the labyrinthodonts, which may have sprung from some crossopterygian fish like Polypterus, and whose pectoral and ventral fins became adapted for terrestrial locomotion. The type was evidently brought into being provoked by, and at the same time favored by, the great extent of low coastal swampy land and bodies of fresh water which bordered the Atlantic seaboard from the Silurian time on.

How the amphibian type arose from the ganoid stock is a matter of conjecture. It

* Certain footprints recently discovered in the upper Devonian show that the type had become established, at least vertebrates with legs and toes.

may, however, be surmised that certain of the lung-fishes or forms like them, adapted for breathing the air direct when out of the water in the dry season, instead of remaining in their mud cells waiting for the rains to fill the lakes or swell the rivers, attempted, like the Anabas, or climbing fish, to migrate in schools overland; or, like that fish, which is said to have become "so thoroughly a land animal that it is drowned if immersed in water," it may have become confined to the land, and, losing its gills, used its lungs only. As a final result of its efforts to walk over the damp soil and mud of swampy regions the unaxial fins may have developed, through the strains and pressures of supporting the clumsy body, into props with several leverage systems; the basalia, instead of remaining in one plane as in a fish's fin, spreading out and becoming digits to support the weight and steady the body while walking. This process was not confined to one or to a few individuals, but, as Lamarck insists in the cases he mentions, it affected all the individuals over a large area. Those individuals with incipient limbs became erased or swamped, and we find no trace of them in the strata yet examined.

Thus far, indeed, Paleontology is silent† as to the mode of origin of the amphibian limb, as it is concerning the origin of arthropod limbs from the parapodia of annelids. Unfortunately, and this is still a weak point in the evolution theory, nowhere do we find, unless we except the Archæopteryx, clear examples of any intermediate forms between one class and another; each species as far as its fossil remains indicate seems adapted to its environment.

There are numerous cases of vestigial structures, but no rudimentary ones showing distinct progressive steps in a change of function. Hence arises the very reasonable view held by some that nature may make leaps, and that new adaptations or organs may be suddenly produced. No inadapted plant or animal as an entire organism has ever been observed either among fossils or existing species. Man has some seventy vestigial structures, but his body as a whole, notwithstanding the disadvantages of certain useless vestiges, is in adaptation to his physical and mental needs.

While the true Carboniferous labyrinthodonts were few and generalized, with gills and four legs; already in the Permian, where we meet with some thirty forms in the Ohio beds alone, and about as many in Bohemia, a great modification and specialization had taken place. Forms like Peleon and Branchiosaurus had gills and four legs; others were like our lizards, as in Keraterpeton; Dendrerpeton and Hylonomus of Nova Scotia were more lizard-like and with scales; others perhaps swam by means of paddles as in Archegosaurus; others, like the 'Congo snake,' were snake-like with small weak legs, as Œstocephalus; some had gills but no legs, as in Dolichosoma, while in others the limbless body was snake-like and scarcely larger than earth worms, as in Phlegethontia of the Ohio and Ophiderpeton of the Bohemian coal measures.

Already, then, in Permian times the stegocephalous type showed signs of long occupation, old age and degeneration. The process of degeneration and reduction in and loss of limbs may have been initiated as far back as the closing centuries of the Devonian.

*Parker and Haswell's Text-book of Zoology, Vol. II., p. 220.

† Paleontology is also equally silent as to the origin of plesisosaurs and ichthyosaurs from their terrestrial digitigrade forbears, though in Archæopteryx we have an unusually suggestive combination of reptilian and avian features. Certain Theriodontia point with considerable certainty to the incoming of mammals, such as the Echidna and duckbill, but as to the steps which led to the origin of the brachiopods, echinoderms, trilobites, of Sirenians and of whales paleontology affords no indications.

The effect of the Appalachian revolution and corresponding physical changes in Europe was by no means disastrous to the Stegocephala, for those of the Liassic, where the conditions must have been more formidable to terrestrial vertebrate life, were abundant, and in some cases at least colossal in size. Whether the salamanders, cœcilians, sirens and Amphiuma of present times are persistent types, survivors of Carboniferous times, or whether the process of modification has been accomplished a second time within the limits of the same class, is perhaps a matter for discussion.

Besides the introduction and elaboration of the air-breathing, four-footed labyrinthodonts, the sloughs and sluggish streams were alive with Naiadites and its allies, forerunners of the Unionidæ, and with them lived shelled Phyllopods, Estheria having already appeared in the Devonian, Leaia appearing in the Carboniferous; and also the larvæ of aquatic net-veined insects, fragments of the imagines of which were detected by Hartt at St. John, New Brunswick.

The coal-bearing strata are largely freshwater beds of fine shale and well calculated to preserve the hard parts of delicate animals, but on general grounds it is evident that the great extent of low lands with extensive bodies of fresh water, communicating with the shallow sea, was most favorable to the development and differentiation of terrestrial life. Though fresh-water and land shells (pulmonates) appeared in the Devonian, they were apparently more abundant in the coal period. Especially rapid was the incoming of the arthropods; both diplopods, some of them very remarkable forms, and chilopods lived sheltered under the bark of colossal lycopods; with them were associated scorpions, harvestmen and spiders. The great profusion of net-veined insects discovered at Commentry, France, shows that this was the age of the lower more generalized or heterometabolous insects, such as cockroaches and other Orthoptera, of Eugereon, may-flies and possibly dragon-flies, etc., our wingless stick-insects being then represented by winged ancestors. At this time also began the existence of insects with a complete metamorphosis, as traces of true Neuroptera and the elytra of a beetle have been detected in Europe. But thus far no relics of flowers or of the insects which visit them have been discovered in Carboniferous times, not even in the Permian, so that the origin of insects with a complete metamorphosis, such as moths, ants and flies, may be attributed to the new order of things, geographical and biological, immediately following the Appalachian revolution.

We do not wish to be understood as implying that the origin of new orders and classes is directly due to geological crises or cataclysms themselves.* On the contrary, the initial steps seem to have been taken as the result of the gradual extension of the land masses and the opening up of new areas; it was the period of long preparation, with long-continued oscillations, the slowly induced changes resulting from the reduction of the mountainous slopes to peneplains, which were most favorable to the

* I find that Wood has already expressed the same idea more fully, as follows: "Both in the palaeozoic and secondary periods, therefore, the complete changes in the fauna which marked their termination do not appear to have been immediate upon the changes of the geographical alignement, but to have required the lapse of an epoch for their fulfilment; and the completeness of that change is perhaps not less the indirect result of the altered alignement, by the formation of continents where seas had been, and the opening out of new seas for the habitation of marine animals, thereby causing a gap in the geological records so far as they have been hitherto discovered, than the direct result of the changed conditions to which the inhabitants of the seas, and even those of the land, came to be subject on account of the entire change in the alignement of the land over the globe." (*Phil. Mag.*, XXIII., 1862, p. 281.)

gradual modification of forms resulting in new types, the gradual process of extinction of useless and senile forms, and the modification and renewal of those which became adapted to the new geographical conditions.

It should be borne in mind that this extension of the low coasts of the continents began in Ordovician times, but the remarkable expansion of our continent after the Appalachian revolution, rather than the upheaval of the plateau itself, so favorably affected plant and animal life that at the dawn of the Mesozoic a great acceleration in the process of type-building was witnessed. Moreover, it seems evident that the variation which took place at this epoch was by no means fortuitous, but determined along definite lines caused by the definite expansion of the continents and their resultant topography.

We have seen that, as a result of the folding and upheaval of the Appalachians, there may have been at the beginning of Triassic time, in addition to the tropical lowlands, a somewhat cooler upland zone, and possibly even snow-clad mountain peaks, with glaciers descending their sides, as we may now witness in New Zealand.

Already on Permian soil reptiles were not infrequent. They were generalized composite forms comprising the Proganosauria, the forerunners of the Hatteria of New Zealand, and the Theriodontia, from which the mammals are now supposed to have been derived. They disappeared at the end of the Triassic, together with the labyrinthodonts, from which the reptiles are thought to have originated. These reptiles having scaly bodies and claws, their habits must have been like those of the lizards of to-day, and they were adapted for hotter and dryer, perhaps more elevated, areas than the stegocephalous amphibians; and these conditions were fulfilled in Triassic and Jurassic times, when the reptilian orders multiplied, all the orders of the class having been differentiated in the Mesozoic era, if not before.

The geographical features throughout the Mesozoic were these: more or less dry and broad plains, vast fresh-water lakes, uplands clad with coniferous forests afterwards to be replaced by forests of deciduous trees; flower-strewn plains overgrown with waving grasses, and jungles with rank growths of bamboo. We can, without going into detail, well imagine that the geographical features of the Mesozoic continents were such as to provoke the appearance of the higher classes of vertebrates. As the land rose higher and the low, swampy coastal areas became more limited, this would tend to restrict the habitat of the stegocephalous amphibians; with a slightly more elevated and dryer coast the incoming and expansion of reptilian life were fostered; with still higher plains and hills, besides the increasing abundance of flowers and other seed-bearing plants and of the insects which visit them, existence for birds became possible, and with them that of a few scattered mammals of small size and generalized structure, with similar insectivorous habits.

During the age of reptiles, when they swarmed in every jungle, throughout the forests and over the plains, competition rose so high that some of them were forced to take flight, and bat-like, provided with membranous wings, the pterodactyls lived in a medium before untried by any vertebrate, and finally there appeared in the Ornithostoma of the Cretaceous a colossal flying reptile, its wings spreading twice as much as any known bird, with a head four feet in length; its long toothless jaws closing on swarms of insects or perhaps small fry of its own type. But the experiment in point of numbers or capacity for extended flight did not succeed. Another type assayed the problem with better success. There appeared feathered and eventually toothless vertebrates with the fore

extremities converted into pinions and the hinder ones retaining the raptorial reptilian form better adapted for aërial life. They eked out a by no means precarious existence on flying insects and seeds, as well as on the life in the soil or by the seaside, and rapidly replaced certain older reptilian types. The class of birds has become about four times as numerous as the reptiles, and outnumbers the mammals nearly six times.

We may now review the zoological changes which took place at the time including the end of the Paleozoic and the opening of the Mesozoic. There was an extinction of the Tetracoralla and their replacement by corals with septa arranged in sixes; an extinction of cystidian and blastoid crinoids, the dying out of old-fashioned crinoids and echinoids (Palæocrinoidea and Palæechinoidea), followed by the rise of their more modern specialized successors. As rapidly as the brachiopods became diminished in numbers their place at the sea-bottom was taken by the more active and in some cases predatory bivalve and univalve molluscs. As the trilobites became extinct their place in part was filled by their probable descendants, the Limuli, which had already begun to appear, the earliest types being Neolimulus, Exapinurus and other forms of the Silurian, and Protolimulus of the Devonian. The Limuli of the Carboniferous, some with short (Prestwichia and Euproops) and others with long tail-spines (Belinurus), suggest long possession of the soil and consequent variation and differentiation.

The Eurypterida shared the fate of the trilobites, and while there was a thorough weeding out of the more typical ganoids, leaving an impoverished assemblage to live on through after ages, that singular primitive vertebrate group, the Ostracodermi, was wholly obliterated.

On the other hand, with the incoming of a new order of vegetation, a great outgrowth of winged insects, the representatives of the orders of Lepidoptera and Hymenoptera, now so numerous in species, began their existence.

By the close of the Appalachian revolution probably all the orders of insects had originated, unless we except the most modified of all, the Diptera, whose remains have not been detected below the Lias. With but little doubt, however, the eight orders of holometabolous insects diverged in the Permian, if not near the close of the Carboniferous, from some protoneuropter ; the progress in the differentiation of genera and families becoming rapid either during the Jurassic or directly after the lower Cretaceous, or as soon as grasses and deciduous trees became in any way abundant.

Very soon, too, after the close of the revolution the ancestral birds and mammals diverged from the reptiles, and of the latter the turtles, plesiosaurs, ichthyosaurs, crocodiles and dinosaurians, and soon after the pterodactyles, came into existence.

As a result of this revolution the molluscan type was profoundly affected, as at the opening of the Triassic siphoniate Pelecypoda, opisthobranchiate Gastropoda and cuttles or belemnites appeared. While a few Orthoceratites lingered on after the revolution, the Ammonites blossomed out in an astonishing variety of specific and generic forms.

In summing up the grand results of the Appalachian revolution and of the times immediately succeeding, we should not lose sight of the fact that the changes in the earth's population were due no less to biological than geological and topographical factors. This process of extinction was favored and hastened by the incoming of more specialized forms, many of them being carnivorous and destructive, as, for example, nearly all fishes and reptiles live on other animals. The

struggle for existence between those which became inadapted and useless in the new order of things went on more actively than at present. The process of extinction of the higher, more composite amphibians (the labyrinthodonts) was largely completed by the multitude of theromorphs and dinosaurs which overcame the colossal Cheirotherium, Mastodonsaurus and their allies.*

During the centuries of the Trias the lowlands became crowded, and the reptilian life was forced in some cases to gain a livelihood from the sea, for at this time was effected the change from small terrestrial reptiles like Nothosaurus to the colossal pleisosaurs and ichthyosaurs, in which digitate limbs were converted into paddles, and the ocean, before this time uninhabited by animals larger than ammonites, cuttles and sharks, began to swarm with colossal vertebrates, the increased volume of their new and untried habitat resulting in a tendency to a corresponding increase in weight, just as whales which possibly evolved from some land carnivora in the early Tertiary waxed great in bulk, the increase in size, perhaps, having been due to the great volume of their habitat, the ocean.

Nothing so well illustrates the advantage to an incipient type as entering a previously uninhabited topographical area, or a new medium, such as the air. In the case of the pterodactyles, the first vertebrates to solve the problem of aërial flight, originating and prospering in the early Mesozoic, they held their own through the Cretaceous, where at their decline they became, as in Ornithostoma, colossal and toothless. We can imagine that the demise of this type was assisted in two ways; those with a feebler flight succumbed to the agile, tree-climbing dinosaurs; while the avian type, waxing stronger in numbers and power of flight and exceeding in intelligence, exhausted the food supply of volant insects, and drove their clumsier reptilian cousins to the wall, fairly starving them out, just as at the present day the birds give the bats scarcely a *raison d'être.*

*After writing the above lines I find the same view expressed in Woodworth's Base-leveling and Organic Evolution. He remarks: "The exact cause of their decline is probably to be sought in the development of the more powerful reptilia" (p. 225). Regarding the circumstances favorable to reptilian life, he also states: "In the development of the peneplain from the high relief of the Permian and again at the close of the Jura Trias the widening out of the lowland, with plains and jungles, near tide-level, followed by depression of the land, must have highly favored the water-loving reptilia. It is to these geographical circumstances, I think, that we must look for our explanation of the remarkable history of this class in Mesozoic times" (p. 226).

3. THE PACIFIC COAST REVOLUTIONS.

It has long been known that there are a greater number of insect faunæ on the Pacific coast and greater variation of species, with more local varieties, than east of the Mississippi river. It has also been shown by Gilbert and Evermann, as well as by Eigenmann, to apply to the fishes of the Columbia and Frazer river basins. "Nowhere else in North America," says the latter, "do we find, within a limited region, such extensive variations among fresh-water fishes as on the Pacific slope." He also points out the noteworthy fact that the fauna is new as compared with the Atlantic slope fauna, and 'has not yet reached a stage of stable equilibrium.' As previously shown by Gilbert and Evermann, "each locality has a variety which, in the aggregate, is different from the variety of every other locality;" and he adds: "The climatic, altitudinal and geological differences in the different streams, and even in the length of the same streams, are very great on the Pacific slope."

It is evident that the variations are primarily due to the broken nature of the Pacific coast region, and to the isolation of the animals in distinct basins more or less

surrounded by high mountain barriers, with different zones of temperature and varying degrees of humidity.

As brought out by the labors of Le Conte, Diller and Lindgren, the Sierra Nevada region has undergone cycles of denudation, and these changes, occurring later than those of the Appalachian region, have doubtless had much to do with the present diversified and variable fauna. The latest writer, N. F. Drake,* states that the western slope of the Sierra Nevada "was probably once a region worn down almost to base-level or to a peneplain. By the uplift of the mountains a great fault was developed along the eastern face and the whole Sierra crust-block tilted to the westward. The streams quickened by the uplift again set to work on the peneplain and carried it to its present condition."

Le Conte † states that the Sierra Nevada was upheaved at the end of the Jurassic period. This corresponded to the Appalachian revolution which occurred at the end of the Paleozoic era.

"But during the long ages of the Cretaceous and Tertiary this range was cut down to very moderate height. * * * The rivers by long work had finally reached their base-levels and rested. The scenery had assumed all the features of an old topography, with its gently flowing curves * * * At the end of the Tertiary came the great lava streams running down the river channels and displacing the rivers; the heaving-up of the Sierra crust-block on its eastern side, forming the great fault-cliff there and transferring the crest to the extreme eastern margin; the great increase of the western slope and the consequent rejuvenescence of the vital energy of the rivers; the consequent down-cutting of these to form the present deep canyons and the resulting wild, almost savage, scenery of these mountains."

* The Topography of California. *Journ. of Geology*, V., Sept.–Oct., 1897, p. 563–578.

† *Bulletin Geol. Soc. Amer.*, II., pp. 327, 328.

This view is further carried out by J. S. Diller, from his studies of the northern part of the Sierra Nevada, including the borders of the Sacramento valley and the Klamath Mountains. He shows that northern California, during the earlier portion of the auriferous gravel period, was by long continued degradation worn down to base-level conditions. "The mountain ranges," he says, "were low, and the scenery was everywhere characterized by gently flowing slopes." * * *

"The topographic revolution consisted in the development out of such conditions of the conspicuous mountain ranges of to-day. The northern end of the Sierra Nevada has since been raised at least 4,000 feet, and possibly as much as 7,000 feet, and a fault of over 3,000 feet developed along the eastern face of that portion of the range."*

According to Lindgren the Sierra Nevada was eroded to, or almost to, a peneplain during Cretaceous times, and the mountains elevated in a later Cretaceous period were worn down during Tertiary times merely to a gentle topography.

The other post-Cretaceous changes of this vast region are thus summarized by Scott from the results of Pacific coast geologists. In the Eocene a long narrow bay occupied the great valley of California, extending northward into Oregon and Washington. At the end of the Eocene or early in the Miocene an elevation in California shifted the shore line far to the west. In the Miocene the Coast Range formed a chain of reefs and islands, and at the close an upturning and elevation of the mountain range took place, though it became higher afterwards. The Coast Range sank again early in the Pliocene and the San Francisco peninsula was an area of subsidence and

* 14th Ann. Rept. U. S. Geol. Survey, Part II., p. 433.

maximum deposition forming the thickest mass (58,000 feet) of Pliocene in North America. The mountains of British Columbia are believed to have been at a higher level than now, as it is supposed that Vancouver and Queen Charlotte Islands probably formed part of the mainland.

At or near the close of the Pliocene the Sierra Nevada increased in height by the tilting of the whole block westward. New river valleys, cut through the late basalt sheets of the Sierras, are much deeper than the older valleys excavated in Cretaceous and Tertiary times, owing to the greater height of the mountains and to the consequent greater fall of the streams. At this time the Wasatch Mountains and high plateaus of Utah and Arizona were again upraised, and the great mountain barrier of the St. Elias, in southeastern Alaska, was likewise thrown up. At this time also, or perhaps later, the mountains of British Columbia were probably raised still higher.* It will be seen from this that the present topography of the western border of our continent including Central America and the Isthmus of Panama belongs to a new topographic era, and fully substantiates the view that the fauna of these regions is very recent compared with that of the Atlantic border, and that the number of nascent or incipient species is much greater.

ALPHEUS S. PACKARD.
BROWN UNIVERSITY.

(*To be concluded.*)

* *Journal Geol.*, IV., pp. 882, 894, 897 and 898. (Quoted from Drake.)

EARTHQUAKES.

COMMANDANT MONTESSUS DE BALLORE, of the French Army, is well known as an authority on earthquakes in general, and especially on the earthquakes of Central America, where he resided for a considerable time some dozen years ago. Besides his own observations he has discussed thousands of others, collected by himself or taken from the extended lists of Mallet (B. C. 1606 to A. D. 1850), Perrey, Fuchs, etc. All of the available material has been sifted and examined, and then discussed in a scientific fashion, to bring out whatever general laws may underlie the statistics.

A collection of some of M. Montessus' pamphlets has lately come into my hands.* They deserve an extended review, but, failing this, the following notes may be of interest.

The relations between the topography of a country—its topographic relief—and the frequency of its earthquakes has been deduced from 98,868 records of shocks at 6,789 centers distributed in 353 regions of the globe. The most general statements that can be made are as follows:

"Regions of great earthquake frequency lie near the greater lines of corrugation of the earth's crust."

"In any group of adjacent seismic regions the earthquake frequency is greatest in the regions of highest relief."

These very general laws may be put into more special forms that are directly proved by the statistics:

I. Mountainous regions are more unstable than plains.

II. Sea-coasts near oceans that rapidly deepen, especially such as are bordered by high mountains, are more unstable than the coasts of shallow seas, especially if such coasts have no mountains near them.

III. The shorter and steeper slopes of mountain chains are the more unstable.

* Relations entre le relief et la sismicité, *Archives des Sciences Phys. et Nat.*, 1895; Le Japon sismique, *ibid.*, 1897; Les Etats-unis sismiques, *ibid.*, 1898; Les Indes Neérlandaises sismiques, *Nat. Tijd. der Kon. Nat. Ver. in Nederlandsch—Indie*, Dl. LVI., 1896; Etude critique des lois de répartion saisonnière des séismes, *Mem. de la Soc. "Alzate,"* tomo IV.; Relation entre la fréquence des tremblements de terre et leur intensité, *Bull. d. Soc. Sismologica Ital.*, Vol. III.; La peninsula ibérica séismica y sur colonias, *Ann. de la Soc. Española de Hist. Nat.*, tomo XXIII.; Seismic Phenomena of the British Empire, *Quar. Jour. Geol. Soc.*, Vol. LII., 1896.